10/563544

20496-498

IAP6 Rec'd PCT/PTO 30 DEC 2005

Method for heat treating cast parts produced from a light metal melt, in particular an aluminium melt

The invention relates to a method for heat treating cast parts produced from a light metal melt, in particular an aluminium melt.

Maximum strengths are demanded of cast parts produced from light metals and which are highly stressed in practical use. This applies in particular to cylinder heads, manufactured from aluminium, of internal-combustion engines, which are exposed, in particular in the case of diesel engines, to considerable loads owing to constantly increasing ignition pressures in practical operation.

High strengths of light metal materials can be obtained by selecting a suitable alloy which is subjected to a heat treatment after casting. Thus, for example in heat-treatable aluminium alloys it is possible to considerably increase the strength level by applying what is referred to as a T6/T7 heat treatment. The maximum increase potential then exists if, after solution treatment, the castings are quenched in a water bath and then stored under heat.

However, the advantages of water quenching are confronted by the decisive disadvantage that high inherent stresses can be established, in particular in the quenching of components with a complex form. These inherent stresses lead to the quenched component indeed having increased strengths but these strengths are cancelled by the drawbacks caused by the inherent stresses or are even exceeded by the drawbacks.

To remedy the drawbacks associated with quenching a thermal post-treatment has been proposed in the article ' Uphill quenching of aluminium: rebirth of a little-known process' by T. Coucher, published in Heat Treating/October 1983, page 30 ff., in which, after quenching, the cast parts are immersed in a bath of liquid nitrogen, of which the temperature is approximately -196°C. They are kept at this low temperature until a homogenous temperature distribution has been established in the cast part.

As soon as the homogeneous temperature distribution is achieved, according to the known method the component cooled to a low temperature is suddenly uphill quenched to a high temperature. The cold component is subjected to a hot jet of steam or immersed in a hot water bath for this uphill quenching.

Uphill quenching to the high temperature brings about equilibrium in the stress profile which has been established during quenching of the cast part. This effect may be explained in that during quenching a decreasing temperature gradient builds up in the direction of the outer regions, starting from the core of the cast part. As a result of the edge layer's attempt to contract as a consequence of cooling, considerable compressive stresses occur between the edge layers and the core zone of the casting.

If the cast part is cooled to a low temperature and then suddenly reheated the edge layer heats up while the core region continues to remain cold. As the core hinders their expansion the outer regions are subject to compressive stresses as a consequence of heating which are the exact reverse of the compressive stresses which are established as a result of quenching. The sudden reheating after the low temperature cooling as such consequently constitutes a reversal of the quenching process both with respect to the measures carried out and with respect to the stresses that occur in the component.

Practical tests have shown that while cast parts may be produced using the known uphill quenching method, of which the inherent stresses are improved compared with cast parts quenched only conventionally, however this mode of operation has proven to be insufficiently effective, in particular for large-scale series production.

Starting from the prior art described above, the object was therefore to create a method with which inherent stresses of castings with a complex form may be eliminated particularly effectively and which can simultaneously be used inexpensively and efficiently in the framework of series production.

Starting from the prior art described above, this object has been achieved according to the invention by a method for heat treating cast parts produced from a light metal melt, in particular an aluminium melt, wherein the cast part is quenched after an

annealing treatment or is quenched from the casting heat, after quenching is cooled to a low temperature and following low temperature cooling is suddenly heated to a high temperature in that it is immersed in a salt melt, of which the temperature is above the boiling temperature of water at normal pressure.

The invention is based on the idea of improving the insufficiently effective uphill quenching of the water steam used in the prior art for this purpose by using a salt melt for rapid heating. The advantage of the use according to the invention of a salt melt consists in that a melt of this type can be heated to temperatures which are clearly above the boiling point of water at normal pressure. Salt melts may therefore be heated to temperatures of 150°C and above without difficulty. Salt melt temperatures of 250°C and above may therefore be established in order to achieve the largest possible temperature difference between the low temperature and the salt melt temperature.

A further advantage of using salt melts as the medium for transferring heat during the suddenly occurring uphill quenching consists in that the heat transfer between a salt melt and the respective casting is much better than in the prior art, wherein the cast part was merely subjected to water steam. In addition there is the fact that salt melts may be controlled substantially better than water steam despite their much higher temperatures.

As a result, the temperature gradient fundamental to the success of the entire heat treatment process may be much improved compared with that in the prior art by uphill quenching, which according to the invention takes place in the salt melt, of the cast parts previously cooled to a low temperature. A high temperature gradient produces a fundamentally higher compensation of the inherent stresses that exist in the respective cast part after quenching.

The invention therefore makes available an inexpensive and reliably executable method for heat treating castings, and in addition this method also leads to cast parts which, compared with the parts produced according to the prior art, have improved properties. High-quality components made of light metal, in particular aluminium, may therefore also be produced using the method according to the invention if these

cast parts have a particularly complex and finely structured form, such as is the case in cylinder heads for internal-combustion engines for example.

In principle, the invention can be applied irrespective of how the respective cast part has been quenched. However, it has proven to be particularly effective if the cast parts have been quenched in a manner known *per se* with the aid of water or a comparably intensively acting quenching agent.

In view of the fact that the greatest possible differences between the low temperature to which the cast parts are cooled after quenching and the uphill quenching temperature of the salt melt, in which the cast parts subjected to intense cooling are uphill quenched, are sought, it is advantageous if the low temperature is less than -180°C. This may be achieved in that, for cooling to the low temperature, the quenched cast part is immersed in liquid nitrogen which at normal pressure has a temperature of approximately -196°C.

A further configuration of the invention already indicated above provides that the salt melt is heated to at least 150°C, in particular to at least 250°C, in order to boost the effect of the temperature differences existing between the intensely cooling and uphill quenching bath.

The salt concentration of the salt melt used according to the invention is preferably at least 98% by weight, so that high bath temperatures are reliably achieved and an equally high thermal conductivity of the melt is ensured with regard to the respectively treated cast part. In this case nitrates and/or chromates, in particular alkali metal nitrates and chromates or alkaline earth metal nitrates and chromates, such as $NaNO_3$, KNO_3 or Na_2CrO_4, are used as the salts.

Practical tests on cylinder heads cast from an AlSi7MgCu0.5 aluminium alloy have impressively confirmed the effectiveness of the method according to the invention.

After a preceding annealing treatment at a temperature of 520°C the cylinder heads were cooled in water to approximately 60°C. After a short rest phase in air low temperature cooling took place in liquid nitrogen at a low temperature of -196°C. The

cooling time lasted until there was a homogeneously uniform temperature distribution in the respective cylinder head. As soon as this state was achieved sudden heating to approximately 240°C took place.

For this purpose, the cylinder heads were immersed in a salt melt at a temperature of more than 250°C and which consisted of 52% by weight $NaNO_3$, 46.4% by weight KNO_3, 1.3% by weight NO_2 and 0.24% by weight Na_2CrO_4. In a first test run the cylinder heads uphill quenched in this manner from the low temperature to the high temperature were cooled to room temperature in that water was washed over them. This served to reliably rinse off the salt residues adhering to the cylinder heads. In a second test run the uphill quenched cylinder heads were cooled to room temperature over a much longer time in still air.

Diag. 1 shows the course of the temperature T of the castings during the heat treatment according to the invention plotted over time. In this case the test run in which cooling of the uphill quenched cylinder heads took place with water is designated 'uphill + water', while the test run in which the subsequent cooling took place with air is labelled ‘uphill + air’.

By applying the mode of operation according to the invention the inherent stresses of the cylinder heads could be reduced to an extent which approximates that which is only achieved in a conventional procedure if, following the annealing treatment, the components are quenched not in water but relatively slowly in air.

Diag. 2 shows the success of the method according to the invention. During cooling in air after the annealing treatment inherent stresses are achieved in the region of only 21 MPa. This value is illustrated in Diag. 2 by the column 'air'. However, the components cooled slowly in air after the annealing treatment have only low strengths. If after the annealing treatment quenching in water takes place, the level of inherent stresses in cylinder heads, which are conventionally cooled in water to 60°C without subsequent low-temperature uphill quenching heating, is 103 MPa. The relevant value is represented in Diag. 2 by the column 'water60'. If, on the other hand, the above described heat treatment according to the invention takes place after quenching in water, in the event that after uphill quenching to 240°C cooling with

water is carried out, there are inherent stresses in the region of 42 MPa (column 'uphill + water' in Diag. 2). An even better reduction in the inherent stresses is achieved if the cylinder heads are cooled slowly in air to room temperature after uphill quenching (column 'uphill + water' in Diag. 2). The cylinder heads heat treated in this manner according to the invention have inherent stresses of 27 MPa and are thus, with substantially greater strengths of the casting, greater by only 6 MPa than the inherent stresses which are achieved purely by cooling in air.

The invention thus allows the advantages of quenching that takes place with a high cooling rate, namely increasing the strength of the respective cast part, to be used without large inherent stresses having to be accepted in the process. The components obtained have high strength and minimised inherent stresses and therefore can cope with even the highest loads in practical operation.